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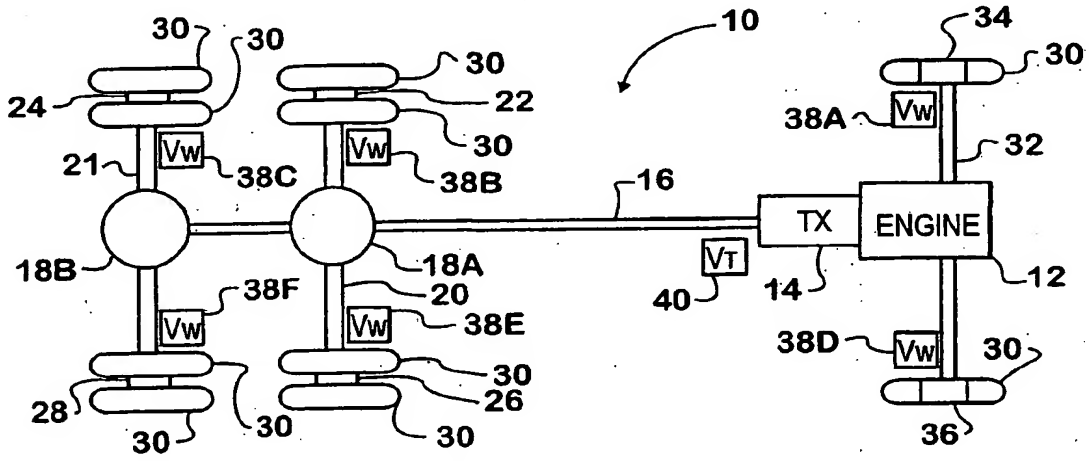

(57) Abstract: A system and a method for detecting compromised vehicle wheel and tire operating characteristics includes detection for out of round new tires, under pressure tires, poor front wheel alignment and off center line loads. The instantaneous rotational velocity signal generated for each wheel (22, 24, 26, 28, 34, 36) by an existing antilock braking system (ABS) 54 provides data for the basic comparison of wheel speed is against an instantaneous indication of vehicle speed. Once calibrated, the system provides operational monitoring of the wheels (22, 24, 26, 28, 34, 36) includes initializing the trip odometer, collecting wheel speeds, and sampling vehicle speed. Tire 30 radius and tolerance data as a function of estimated wear and tire temperature. Tire 30 temperature is in turn a function of ambient temperature and trip distance. The rotational velocities for the wheels (22, 24, 26, 28, 34, 36) are estimated as functions of vehicle speed and the updated tire radius data. Wheels rotational velocity is compared to estimated velocity and the difference is compared to the allowed, updated tolerances. A possible pressurization error is indicated if one wheel departs outside of the updated tolerances from estimated rotational velocity.

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METHOD AND APPARATUS FOR WHEEL CONDITION AND LOAD POSITION SENSING

BACKGROUND OF THE INVENTION

1. Technical Field:

The present invention relates to a method and apparatus for monitoring wheel conditions on a moving truck and more particularly to a method and apparatus for detecting wheel alignment and inflation problems and for monitoring load positioning.

2. Background to the Invention:

Poor wheel alignment and tire under inflation are factors contributing to premature tire wear and poor vehicle handling. A system which alerts a vehicle operator of low tire pressure and misalignment would help control one of the factors contributing to the accelerated wear of tires. Unfortunately, the direct provision of pressure sensors in wheels to monitor tire pressure has proven unreliable and expensive. Pressure sensors mounted in wheels are subjected to a hostile environment of high temperatures, road shock and high rotational velocities. The data transmission linkage from the wheel to the vehicle is necessarily indirect and adds expense to the system, and it requires an independent power supply, such as a battery, which must periodically be removed from the tire for replacement.

Tire pressure directly relates to the rolling radius of a tire, which shrinks with reduced pressure. As the tire's rolling radius is compressed, side wall flex increases causing the tire's temperature to increase. Increased operating temperature of a tire promotes degradition of the synthetic rubber of the tire and results in excessive tire wear. As an alternative to measuring tire pressure, a wheel's rotational speed can also be measured as an indirect indication of tire under inflation. The increasingly widespread use of antilock braking systems (ABS) on cars and trucks affords a convenient source of wheel rotational speed information which can be used to implement pressure monitoring methods involving wheel rotational speed monitoring.

United States Patent 6,064,936 to Nakajima describes a system utilizing an ABS to provide inputs for tire pressure monitoring system. While increases in one wheel's velocity suggest low inflation of the tire mounted on that wheel, other circumstances may exist which be the cause of a relative increase in wheel angular velocity. The Liu, et al. reference, United States Patent 5,760,682 develops calibration coefficients to compensate for factors such as wheel slippage, rough road fluctuations, vehicle cornering, and uphill and downhill travel. Desirable though is a system which can identify different conditions affecting wheel rotational velocity so that the proper corrective steps may be taken.

Numerous patents relate specifically to the application of indirect tire pressure measurement using ABS wheel speed sensors on automobiles. With trucks additional issues are raised due to the much higher sidewall stiffness of tires compared to automobile tires (and consequent relatively lower sensitivity of rolling radius to tire pressure) and the differences in wheel layout used for trucks, for example 4X6 (a front steering axle with two tires with a rear driven axle carrying four tires) and 6X10 (a front steering axle with two rear driven axles, each with four tires) wheel arrangements. Truck suspensions are designed for maximum load conditions and loading varies much more than for passenger autos. Vehicle speed for trucks is commonly measured by a tachometer. The tach is attached to track the rotational velocity of a drive shaft installed between the vehicle's transmission and a rear end differential. As a result measured velocity is proportional to the average rotational velocity of the driven wheels. ABS wheel sensors provide an alternative source of data with which to generate vehicle speed, among values for other operating variables.

SUMMARY OF THE INVENTION

The objects, features, and advantages of the invention will be apparent from the written description that follows. The invention provides an apparatus and a method for detecting compromised vehicle wheel and tire operating characteristics. Among the condition indication of which can be detected are out of round new tires, under pressure tires, poor front wheel alignment and either a longitudinally or latitudinally off center load. The invention provides that an instantaneous rotational velocity signal for each wheel is generated, typically using an existing antilock braking system (ABS). Wheel speed is compared against an instantaneous indication of vehicle speed, which is usually, but not necessarily, generated from the rotational speed of the drive shaft take-off from the vehicle's transmission.

Operation of the method and system requires calibrating newly mounted tires. As part of the calibration process it is determined if each newly installed tire is within tolerances for the tire and if the front tires appear to be correctly aligned. Calibration is done to generate a scalar relating wheel rotational velocity for each wheel to straight line vehicle speed. Once scalars have been obtained for each wheel they are stored, and then adjusted for estimated wear of the tires as a function of distance traveled. To obtain these numbers, the distance traveled on the tires currently mounted on the wheels and distance traveled since a current trip began are tracked. Vehicle speed can be calibrated utilizing the global positioning system, which involves installation of the appropriate sensor on the vehicle.

Operational monitoring of the wheels includes initializing the trip odometer, collecting wheel speeds, and sampling vehicle speed. Tire radius and tolerance data are generated as a function of estimated wear and tire temperature. Tire temperature is in turn a function of ambient temperature and trip distance. Rotational velocity of the wheels are estimated as functions of vehicle speed and the updated tire radius data. Rotational velocity for each wheel is subtracted from estimated velocity and the difference is compared to the allowed, updated tolerances. A possible pressurization error is indicated if one wheel departs outside of the updated tolerances from estimated rotational velocity.

Additional effects, features and advantages will be apparent in the written description that follows.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself however, as well as a preferred mode of use, further objects and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Fig. 1 is a schematic view of a vehicle drive train.

Fig. 2 is a block diagram of a data processing system and connections to external data inputs used in practicing the invention.

Fig. 3 is a data flow diagram.

Figs. 4 A-C are a flow chart of an algorithm used in practicing the invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings, a preferred embodiment of the invention and its manner of use will be described. Fig. 1 illustrates a vehicle drive train 10 to which the system and method of the invention are applied. Vehicle drive train 10 provides for the application of motive power generated by an engine 12 to each of a plurality of rear drive wheels 22, 24, 26 and 28. Engine 12 applies power directly to a transmission 14, which includes a plurality of step down gears. Transmission 14 turns a drive shaft 16 which is coupled between the output end of transmission 14 and forward rear differential 18A and aft rear differential 18B. Forward rear differential 18A drives wheels 22 and 26 mounted on forward rear axle 20 and aft rear differential 18B drives wheels 24 and 28 mounted on aft rear axle 21. Wheels 22 and 26, and wheels 24 and 28 are mounted on the outside ends of rear axles 20 and 21, respectively. Forward left and right steering wheels 34 and 36 are mounted on the outside ends of forward steering axle 32. Each of the rear drive wheels 22, 24, 26 and 28 support two tires 30. Forward wheels 34 and 36 each have one tire 30. Vehicle drive train 10 is illustrated as an 8X10 configuration (i.e. two driven axles) commonly found on trucks, but the invention is equally applicable to a 4X6 configuration (i.e. one driven axle).

The vehicle incorporating vehicle drive train 10 is equipped with an antilock braking system (ABS) which provides wheel speed sensors for each wheel. These include a wheel rotational speed sensor 38A positioned adjacent and on left forward wheel 34. Wheel rotational speed sensor 38B is adjacent drive wheel 22. Wheel rotational speed sensor 38C is adjacent drive wheel 24. Wheel rotational speed sensor 38D is adjacent wheel 36. Wheel rotational speed sensor 38E is adjacent drive wheel 26. Wheel rotational speed sensor 38F is adjacent drive wheel 28. Vehicle speed may be generated from a tachometer 40 mounted to the output end of transmission 14. The signal generated from tachometer 40 represents an average of the rotational velocity of the vehicle's rear wheels 22, 24, 26 and 28. Vehicle speed is generated by factoring the tachometer's output by a standard wheel radius and the step down ratio of the rear differentials to produce a desired speed. However, as is well known, rear drive wheels are subject to

slippage during acceleration (and deceleration) and in climbing and descending from hills, among other situations. Accordingly, the speed signal produced by tachometer 40 is not the most accurate way to measure speed, though it remains commonly employed. As will be described below, one embodiment of the invention eliminates the vehicle speed tachometer 40 and substitute the ABS sensors 38A-F as the data gathering element in a speed signal generating system.

Fig. 2 is a block diagram illustrating the component elements of the present invention. A wheel and tire condition monitoring computer 42 is connected to receive data inputs from the vehicle speed tachometer 40, an ambient temperature measuring thermometer 44 and a global positioning sensor (GPS) 48. Tachometer 40 and GPS 48 are optional components. Computer 42 is equivalent in power to common personal computers contemporary to the date of preparation of this application, although the computational burdens entailed by the method of the invention can be effectively carried out on a minimal system based on an embedded micro computer system. Computer 42 requires some writeable, non-volatile memory 52 for the storage of long term data and programs. In addition, computer 42 is connected to an antilock braking system computer 54 whereby computer 42 reads wheel rotational speeds (or output pulses) passed through from wheel rotational sensors 38A-F. (For a 4X6 drive train configuration there are only four rotational sensors.) The functions of ABS computer 54 and computer 42 could be combined. However, given that the ABS computer must give priority to the execution of antilock braking functions, prudence suggests the use of separate computers. The data link 55 from ABS computer 54 to computer 42 is preferably provided by a link conforming to the SAE J1939 standard. Computer 42 must be able to provide warning signals to an operator and accordingly the computer is attached to an operator input/output interface 50. I/O interface 50 also allows the input of tire data at the time of installation of new tires 30 on a vehicle. The stored data in memory 52 includes odometer registers 53.

I/O interface 50 includes warning indicators mounted within a truck cab which may emit aural warnings or include warning lights for the indication of particular problems with particular wheels. The interface includes a numerical keypad or other interface for the entry of data relating to tires for each wheel of the vehicle. The minimum data to be entered includes tire size, tread depth, mileage when installed and manufacturer. Wear profiled are supplied in a data base indexed by manufacturer for operation at rated inflations and loads. To accommodate replacement of a tire, positions are also entered. Further data may

include a wear profile for each tire against distance traveled. Upon installation a base mileage is saved for projecting tire rolling radius over the life of the tires. Data entry initiates a calibration algorithm function to obtain and store new tire rolling radius for each tire and to calibrate the vehicle odometer and speedometer.

Fig. 3 is a data flow diagram illustrating data manipulation steps for two preferred embodiments of the invention. A highly accurate, more expensive version of the system relies on vehicle geographical coordinate data 300, preferably supplied by the global positioning sensor 48.

If available, vehicle coordinate data 300 is passed to vehicle speed and direction calculation at algorithm 302. Coordinate data 300 is refreshed on a periodic basis, e.g. once a second. A minimum vehicle speed will support consistently reliable calculations of velocity. At the time of filing of this patent a speed of 50 k.p.h. is adequate. Improved accuracy in the global positioning system will allow for determination of vehicle speed and direction at lower speeds. Sampled speed over consecutive data samples is a direct matter of determining the distance between successive sampled location coordinates and dividing by the elapsed time.

It will now be obvious to those skilled in the art that such a direct calculation does not allow for the possibility that the vehicle followed a path other than the most direct one between successive locations corresponding to GPS 48 initiated inquiries. Vehicle turns, whether turns along a highway at a sustained velocity, or events involving an actual change of speed, will be reflected by changes in speed determined by the vehicle speed and direction calculation algorithm 302 if using GPS data. In the first case, the detected change in speed may not be the product of an actual change in vehicle velocity. Thus the calculations of calibration algorithm 304 and wheel algorithm 306 depend, primarily, on the vehicle following a constant direction. Substantially unvarying vehicle speed for a sustained period, for example 2 minutes, is taken as indicating a constant vehicle direction, permitting full execution of the calibration and wheel algorithm 304 and 306. If a vehicle has a steering position sensor, then an input from that sensor can be used to determine straight line operation.

Calibration algorithm 304 is entered upon installation of one or more new or replacement tires. Data is entered relating to all replacement tires, and their positions. The vehicle is then driven at a constant

speed on a straight stretch of road allowing speed data V_o to be developed and the individual wheel speed signals (V_{1-k}) be generated. As described below, individual wheel signals are analyzed to determine conformity of the newly fitted tire(s) to expected values.

Once wheel speed signals are brought into conformance with expected operating characteristics, the calibration algorithm 304 passes wheel by wheel velocity reference values V_{1ref} - $v_{k\,ref}$ to the wheel algorithm for use in detecting later occurring changes to tires, such as premature wear or low pressure. The reference values are found by applying the following general equation to the specific cases:

$$(1.)\quad V_{iref} = 1/t(\grave{o}V_i dt) \quad for\ 0,T$$

The calibration algorithm 304 may supply a vehicle speed reference value V_{ref} to be used for calibration of the speedometer and odometer signals. V_{ref} is tailored to the specific tire set installed on the vehicle and may be subject to further correction factors relating to tire wear. The use of V_{ref} may depend upon whether GPS data is available on the vehicle.

Alternative sources for vehicle speed may be utilized where no GPS unit 48 is provided on a vehicle. Tachometer 40 is one source of speed data 310. As described above, tachometer data represent an average of drive wheels' rotational velocity. Wheel speed averages 312 can supply a velocity signal (V_{out}) which is an average of wheel rotational speeds for all of the which, i.e.

$$(2.)\quad V_{out} = \left(\sum_{i=1}^{K} V_i\right)/K$$

If one signal of the wheel rotational signal departs by more than a threshold deviation from the average for the remaining wheel rotational speed signals, that value may be dropped from the calibration of vehicle speed before the value is passed to vehicle speed and direction calculation algorithm 302 and application to the calibration algorithm 304. Vehicle direction determinations need not change greatly with changes in the source of the velocity signal. Neither the tachometer unit 40 or the GPS unit 48 is strictly required to practice the invention and either or both may be eliminated from the vehicle. Use of GPS unit 48 has a number of benefits however including increased accuracy in the calculations called for and as a way of

updating calibration of the vehicle speedometer and odometer. Where both are eliminated vehicle speed is determined using equation 2. Where the GPS 40 is available, vehicle speed is still determined using equation 2, but the result is calibrated using GPS 40 data.

Once calibration is complete the wheel algorithm 306 is initiated, utilize the raw wheel rotational velocity signals $V_{1\text{-}k}$, $V_{1\ ref}$ through $V_{k\ ref}$ and indication of the vehicle traveling in constant direction.

Referring now to Figs. 4A-C, a flow chart is described illustrating one method for practicing the invention adapted to serve as an algorithm executable on a computer 42. Those skilled in the art will recognize that the sequence of steps of the program is subject to considerable rearrangement without changing the essence of the processes. The program is initiated upon starting step 60 the vehicle on which the wheel and tire monitoring system is installed. It is immediately determined, from operator input on I/O interface 50, if new tires have been installed. If not, processing branches to step 84 along the NO branch from decision box 62. If new tires have been installed calibration of the tires is required and processing follows the YES branch. The calibration of any new or replacement tires 30 requires the data inputs described above, including the expected rolling radius of the tire at each wheel position, the wear factor expected for that position and the tolerances the rolling radius must meet.

A tire, if out of round, will exhibit a variable rolling radius. A variable rolling radius results in the wheel on which the out of round tire is mounted exhibiting a varying rotational velocity profile. At step 70 the rotational velocity profile for each wheel is examined. If one or more wheels is out of round it is determined at decision step 70 and the NO branch (i.e. No to the question, are wheel speeds constant?) is taken to step 78 where a warning is issued that one or more tires 30 suffer from a possible out of round condition. Processing is then indicated as terminating at step 79, indicating opportunity for remedial action to be taken before calibration is resumed.

If wheel speeds are constant at the outset of calibration then the YES branch is taken from decision step 70 to decision step 72. At decision step 72 the rotational velocity for each wheel is compared with the expected wheel velocity as determined from vehicle speed (derived from tachometer 40). The output from tachometer 40 is assumed to be equated to a vehicle speed based on knowledge of the rear end differential

ratios and a standard wheel rolling radius, the latter of which is a characteristic which compromises tachometer 40's accuracy as an indication of vehicle speed. Measured wheel speeds should match, or fall within a predetermined margin of error of the estimated speeds. If they do, the YES branch is taken from decision step 72 and scalars for each wheel are calculated to equate measured wheel rotational velocity to the estimate for wheel rotational velocity derived from vehicle velocity at step 80. After the scalars are calculated, a database on the tires 30 and the scalars calculated at step 80 is flagged as usable. At step 82 an odometer is initialized which records the distance traveled on the tires. Where fewer than the entire set of tires is replaced, individual odometers may be set for each wheel. Processing than can continue to step 84 for normal operational processing.

Wheel rotational velocities which are constant, but out of tolerance, do not necessarily indicate any one problem, although the circumstances under which the deviant rotational velocities occur exhibit a correlation with certain compromised tire, or wheel, operating characteristics. Frequently, a deviation from predicted wheel rotational velocity indicates a deviation from tire rated pressure. However, during mounting of tires it is probable that the tires were correctly pressurized for the calibration test. Under these circumstances other possible problems should be considered and are highlighted through the portion of the algorithm occurring following the NO branch from decision step 72.

Among the problems which may be present are an alignment problem which can occur with either of the front wheels 34 and 36. Accordingly, along the NO branch from decision step 72 it is determined if the wheels exhibiting unexpected rotational velocities are front wheels. If not, processing advances along the NO branch to step 77 where an indication of a tire out of tolerance warning is issued. If a wheel exhibiting an out of tolerance variation from expected rotational velocity is a front wheel then the YES branch is taken to step 76 allowing signaling of a possible alignment error. From step 76 processing continues to step 77 to allow generation of a possible tire size outside tolerance signal to be generated. Step 77 may also be taken as possible indication of an incorrect entry of data, which would also require correction. From step 77 processing is terminated by step 79 to allow corrective steps to be made.

Operational monitoring of wheel and tire condition begins at step 84. The accuracy of certain measurements is enhanced by estimating operational tire temperature, the formula for the generation of

which utilizes the distance traveled on the current trip. Step 84 provides for initialization of a trip odometer to provide this input. Initially, data points are collected for several variable inputs. Among the variable inputs developed are measured wheel speed, vehicle speed, and, if available, positional data provided by a global positioning sensor unit. The data sampling is represented as a sequence of steps 86, 88 and 90. Sampling continues until statistically significant accumulations of data have been collected (step 100). Positional data is collected to provide a measurement of straight line distance traveled against time. This data is used to generate a vehicle velocity measurement which can be used to calibrate the vehicle speedometer, and in part compensate for distortions introduced into the speed measurement by wear of the tires or inadequate inflation of tires mounted on the drive wheels 22, 24, 26 and 28. A sufficient number of data points is collected from GPS 48 to provide a more accurate measurement of vehicle speed than is provided by the tachometer 40. Speed during data sampling is monitored and if a deviation from a consistent speed is detected sampling is aborted at step 99 due to possible initiation of a turn.

Once a statistically significant sample set has been collected processing of the data begins. At step 102 the signals from the GPS (if available) are used to calibrate the instantaneous measurement of vehicle speed. Next, at step 104, the rotational velocity of each wheel is calculated. At step 106 the odometer is interrogated to retrieve the distance traveled on the tires at each wheel location. This figure is used to update the estimate of each tire's rolling radius and to update the allowable variation in that diameter. Tire characteristics are also a function of tire temperature, which, as is well known, can increase pressure. Tire temperature is indirectly calculated from the distance traveled on the instant trip, or since the last prolonged stop and ambient temperature. From these calculations an estimate for the rotational velocity for each vehicle wheel is generated from the estimated wear, estimated tire temperature and vehicle speed. The estimated and measured wheel rotational speeds are compared at step 112 to determine if the differences between measured values and estimated values are within tolerances. If the differences are within tolerances, processing is returned to step 86 to collect another data set along the YES branch from decision step 112. The return loop includes a variable reinitialization and update step 114.

Certain diagnostic processes require tracking certain designated variables for longer periods then each sample collection period. For example, a running tally of wheel rotations, and relative wheel speed

during a trip may be maintained for comparison with the other wheels to detect situations that develop during a trip that might otherwise falsely indicate a pressurization problem. These values may be updated at step 114.

The NO branch from decision step 112 advances the algorithm to a series of diagnostic tests represented by steps 116-125. Initially it is determined if there is side to side pattern in the variation of wheel speeds, e.g. are wheels 22, 24 and 34 turning faster than expected compared to wheels 28, 26 and 36. Such a pattern can indicate that the vehicle is overloaded to one side, which may occur due to poor loading or shifts in a load during travel. It may be observed that this test is depicted as occurring only if some of the wheels have a rotational velocity outside of tolerances for the observed vehicle speed, which implies a minimum wheel rotational velocity variation as a threshold before an unbalanced load is indicated. This test can be moved ahead of the wheel speed out of range step 112, provided a set of threshold differences in side to side wheel rotational speed are applied. If load is off balance along the roll axis, wheels on one side of the vehicle will show a speed difference compared to wheels on the other side.

The NO branch from step 116 advances processing along a path where the likely cause of wheel rotational velocity is loss of tire pressure. At step 118 it is determined whether the wheel departing from norms is a front wheel. Whether it is or not, a warning is issued of a possible pressurization problem (step 122). If the wheel is a front wheel a second warning is issued also indicating the possibility that an alignment error may have developed (step 120).

Careful readers will note that multiple problems can occur simultaneously. For example, tire pressure may be low and the vehicle load out of balance. It is conceivable that a slow leak leading to developing low tire pressure could contribute to a shift in load, also putting a vehicle out of acceptable balance. Step 123 following step 124 may be used to detect the largest variation in wheel speed among wheels on one side of a vehicle for recomparison to its estimated rotational speed. A YES result at step 123 returns process execution to step 118. A NO result results in processing returning to step 114.

The system and method of the present invention must have a mechanism for distinguishing turns from load imbalances. A secondary benefit of the ability to detect the onset and termination of turns is the

possibility of replacing the automatic cancellation mechanism for turn signals. A side to side variation in wheel speed may indicate an unbalanced load, or it may indicate that the vehicle is turning, in which case the inside wheels will turn more slowly than the outside wheels. Step 125, which follows along the YES branch from decision step 99 is used to determine occurrence of a turn. Turns are likely to occur as temporary side to side variations in wheel rotational velocity which span several sampling intervals. To determine the occurrence of a turn the mid-term wheel rotational velocity signals may be recalled to determine the persistence of the side to side variation. Along the YES branch from step 125, i.e. detection of a turn, step 126 may be provided to activate the turn signal if not on during a turn. At step 128 the difference in wheel speeds is compared until the side to side difference approaches 0. Cancellation of the signal follows that event after a brief time delay at step 130. Since data points collected in a turn are distorted processing is returned to step 114 to reset counters before the collection of a new set of data points.

The system and method of indirect tire pressure measurement using ABS wheel speed sensors of the present inventions has several advantages. Trucks require greater sensitivity of measurement due to the much higher sidewall stiffness of tires compared to automobile tires. Various drive train patterns are allowed for including both 4X6 and 6X10 wheel arrangements. Load imbalance, wheel alignment, out of specification tires and other problems are also handled.

While the invention is shown in only one of its forms, it is not thus limited but is susceptible to various changes and modifications without departing from the spirit and scope of the invention.

What is claimed is:

1. Apparatus for monitoring the condition of each of a plurality of wheels of a vehicle, the apparatus comprising:

a computer;

a wheel rotational velocity sensing system generating wheel rotational speeds respective to each wheel, coupled to the computer to apply rotational velocity signals for each wheel to the computer;

a vehicle speed signal generator;

computer memory in which is stored data relating to tire wear rates for tires mounted on each wheel, tire mileage since installation, current trip mileage, running average wheel rotational velocities, and a scaling factor for estimating wheel speed based on the vehicle speed signal; and

a stored program for execution on the computer for referencing the stored data in determining out of tolerance wheel speeds indicative of compromised operating conditions.

2. Apparatus as claimed in Claim 1, further comprising an input/output interface allowing an operator to enter data relating to newly installed tires.

3. Apparatus as claimed in Claim 2, further comprising:

an ambient temperature sensor; and

the stored program further referencing ambient temperature in determining out of tolerance wheel speeds.

4. Apparatus as claimed in Claim 3, further comprising:

a global positioning sensor; and

a stored program for execution on the computer for calibrating measured vehicle speed against changes in position of the vehicle determined by the global positioning sensor.

5. Apparatus for detecting compromised vehicle wheel and tire operating characteristics, the apparatus comprising:

wheel rotational velocity sensors mounted on the vehicle in relation to each wheel and generating an instantaneous rotational velocity signal for each wheel;

a vehicle instantaneous speed signal generator;

an odometer indicating distance traveled on the tires currently mounted on the wheels;

a trip odometer indicating distance traveled since a current trip began;

computer memory storing and wheel and tire condition monitoring algorithm and data including the instant distance indications, wheel by wheel scalars for the currently mounted tires relating rotational velocity to vehicle speed, tire wear profile data and recent average vehicle speed; and

a computer coupled to the computer memory for reading and writing the data and executing the wheel and tire condition monitoring algorithm for detecting compromised wheel and tire conditions.

6. Apparatus as claimed in Claim 5, further comprising:

an operator interface allowing entry of data relating to the newly mounted tires including running radius and running radius tolerances at rated pressure.

7. Apparatus as claimed in Claim 6, wherein the wheel and tire condition monitoring algorithm further comprises:

means for calibrating newly mounted tires determining if each newly installed tire is within tolerances and generating a scalar relating wheel rotational velocity to straight line vehicle speed;

means for indicating a possible out of alignment condition for any wheel varying out of tolerance during calibration;

means for recording all calibrations on operator entered data;

means for operational monitoring of the wheels including means for initializing the trip odometer, means for collecting wheel speeds and means for collecting vehicle speed;

means for updating tire radius and tolerance data as a function of estimated wear and estimating wheel rotational velocity as a function of vehicle speed;

means for comparing wheel rotational velocity to estimated velocity and comparing the difference to the allowed, updated tolerances; and

means for indicating possible pressurization error if one wheel departs outside of the updated tolerances from estimated rotational velocity.

8. Apparatus as claimed in Claim 7, the wheel and tire condition monitoring algorithm further comprising:

means utilizing the running averages for wheel rotational speeds for detecting side to side variation in wheel rotational speeds;

threshold means responsive to detection of side to side variation in wheel rotational speeds for deciding if the variation in wheel rotational speeds indicates onset of a turn; and

duration means responsive to detection of side to side variation in wheel rotational speeds for determining if the variation indicates an out of balance load.

9. Apparatus as claimed in Claim 8, further comprising:

a thermometer coupled to the computer to apply ambient temperature signals thereto;

the means for updating tire radius and tolerance data as a function of estimated wear being further responsive to the ambient temperature signal.

10. Apparatus as claimed in Claim 9, further comprising:

a global positioning sensor;

means for calibrating the vehicle instantaneous speed signal and the odometer and trip odometer indications based on comparison with estimates of speed and distance traveled derived from position readings supplied by the global positioning sensor.

11. Apparatus as claimed in Claim 10, wherein the vehicle speed signal generator takes wheel rotational speed as inputs calibrated by position readings from the global positioning sensor.

12. Apparatus as claimed in Claim 11, wherein the vehicle speed signal generator is a tachometer counting rotations of a drive shaft from the output end of a transmission.

13. Apparatus as claimed in Claim 12, wherein the wheel rotational velocity sensors comprises a vehicle anti-lock braking system.

14. A method for detecting compromised vehicle wheel and tire operating characteristics, the method comprising the steps of:

generating an instantaneous rotational velocity signal for each wheel;

generating an instantaneous indication of vehicle speed;

calibrating newly mounted tires determining if each newly installed tire is within tolerances and generating a scalar relating wheel rotational velocity to straight line vehicle speed;

tracking distance traveled on the tires currently mounted on the wheels;

tracking distance traveled since a current trip began;

keeping wheel by wheel scalars for the currently mounted tires relating rotational velocity to vehicle speed, tire wear profile data, and recent average vehicle speed;

means for indicating a possible out of alignment condition for any wheel varying out of tolerance during calibration;

means for recording all calibration an operator entered data;

means for operational monitoring of the wheels including means for initializing the trip odometer, means for collecting wheel speeds, means for collecting vehicle speed;

updating tire radius and tolerance data as a function of estimated wear and estimating wheel rotational velocity as a function of vehicle speed and the updated tire radius data;

comparing wheel rotational velocity to estimated velocity and comparing the difference to the allowed, updated tolerances; and

indicating possible pressurization error if one wheel departs outside of the updated tolerances from estimated rotational velocity.

15. A method as claimed in Claim 14, further comprising the steps of:

measuring ambient temperature and modifying the tire radius and tolerance data as a function

in ambient temperature.

16. A method as claimed in Claim 15, further comprising the steps of:

using a global positioning sensor repeatedly to determine position;

calculating vehicle speed from positions determined by the global positioning sensor; and

calibrating distance traveled and speed measurements based on the vehicle speed calculated from the positions.

17. Apparatus for determining speed for a vehicle, comprising:
auto lock brake system including rotational velocity signal generators for each wheel;

a rotational velocity signal averager for producing a raw average speed; and

a source of calibration value for adjusting the raw average signal to produce a velocity signal for the vehicle.

18. Apparatus as claimed in Claim 17 wherein the source of the calibration value includes a tire calibration algorithm operating on data inputs including initial tire size and tread depth.

19. Apparatus as claimed in Claim 18, wherein the source of the calibration value includes a tire calibration algorithm operating on data inputs including initial tire size and tread depth.

20. Apparatus as claimed in Claim 17, where the rotational velocity signal generator includes a means for comparing the rotational velocity of any one wheel against an average speed of the remaining wheels and eliminating any one wheel if its rotational velocity departs from the average by more than allowable deviation.

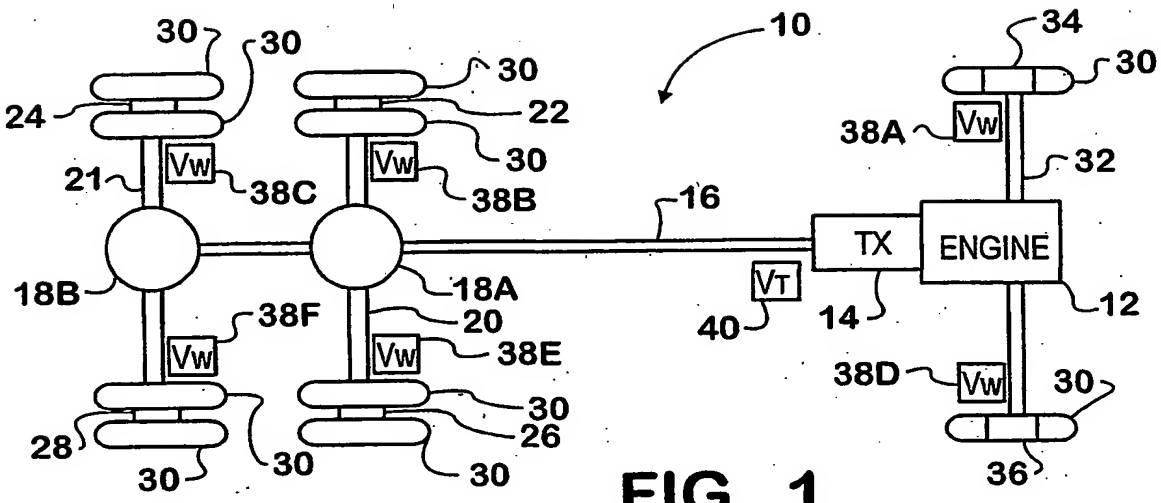
10
30
30
30
30
24
22
30
21
Vw
38C
Vw
38B
16
34
30
38A
Vw
32
TX
ENGINE
18B
18A
VT
40
14
12
38F
20
Vw
Vw
38E
38D
Vw
30
30
30
28
26
30
30
30
36

FIG. 1

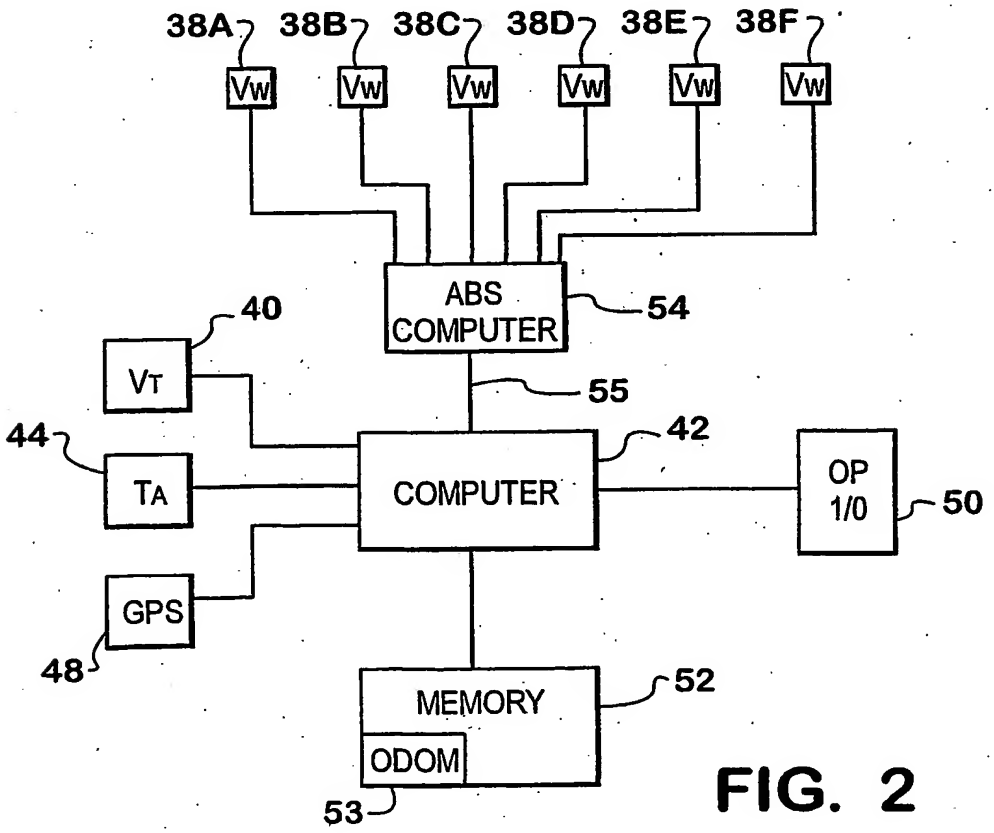
38A
38B
38C
38D
38E
38F
Vw
Vw
Vw
Vw
Vw
Vw
ABS
COMPUTER
54
40
VT
55
44
42
TA
COMPUTER
OP
1/0
50
GPS
48
MEMORY
52
ODOM
53

FIG. 2

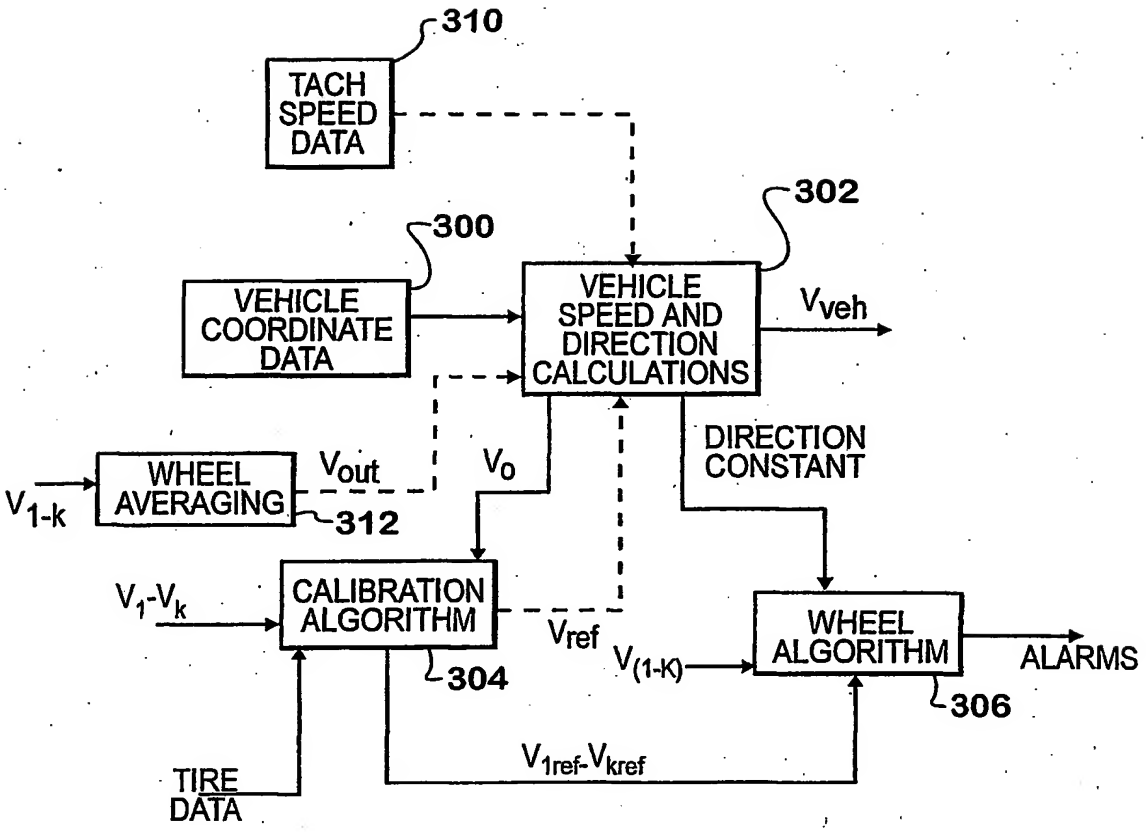
310
TACH SPEED DATA
302
300
VEHICLE COORDINATE DATA
VEHICLE SPEED AND DIRECTION CALCULATIONS
Vveh
DIRECTION CONSTANT
V1-k
WHEEL AVERAGING
Vout
312
Vo
V1-Vk
CALIBRATION ALGORITHM
304
Vref
V(1-K)
WHEEL ALGORITHM
306
ALARMS
TIRE DATA
V1ref-Vkref

FIG. 3

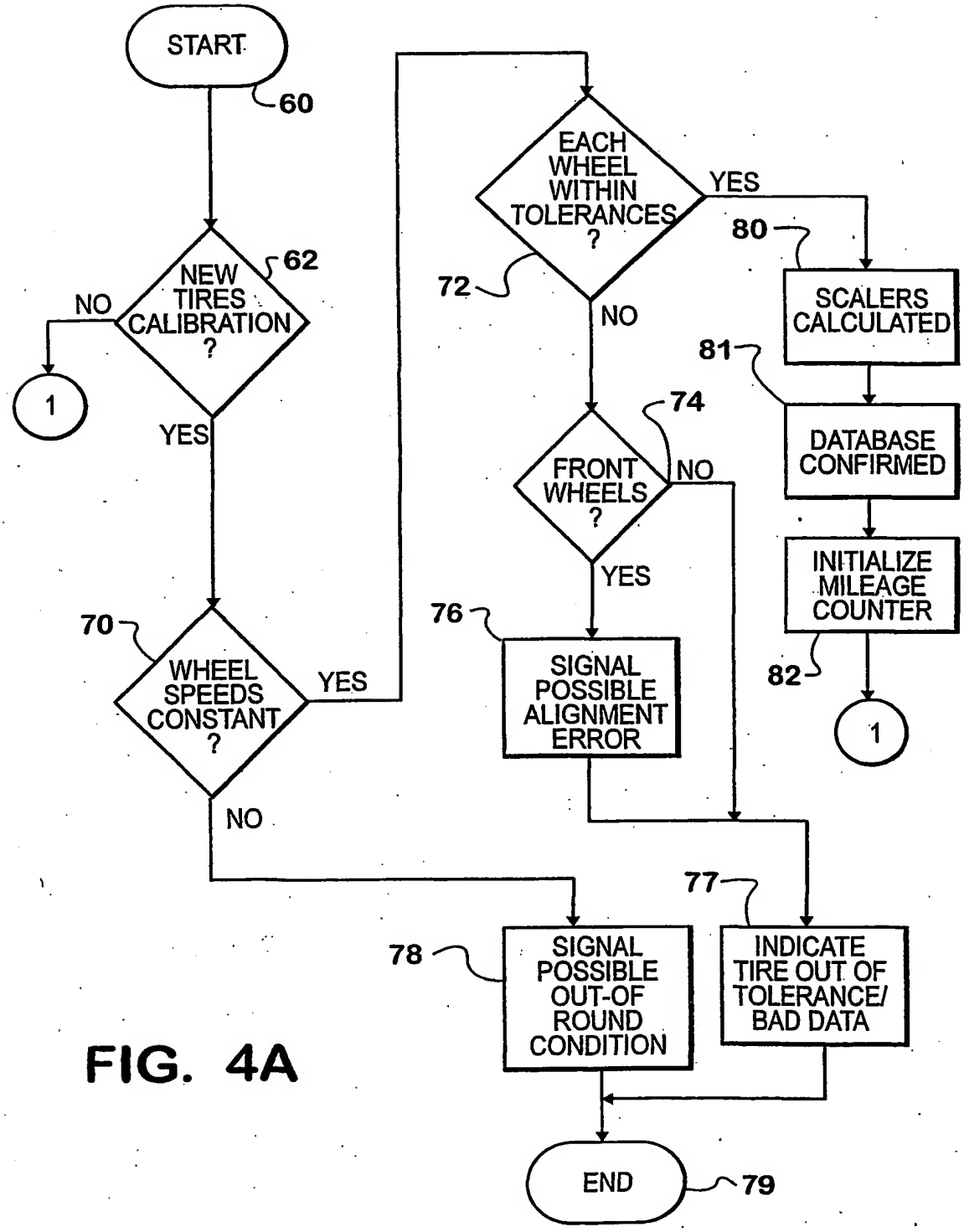
START
60
NEW TIRES CALIBRATION ?
62
NO
1
YES
WHEEL SPEEDS CONSTANT ?
70
YES
NO
EACH WHEEL WITHIN TOLERANCES ?
72
YES
NO
FRONT WHEELS ?
74
NO
YES
SIGNAL POSSIBLE ALIGNMENT ERROR
76
SCALERS CALCULATED
80
DATABASE CONFIRMED
81
INITIALIZE MILEAGE COUNTER
82
1
SIGNAL POSSIBLE OUT-OF ROUND CONDITION
78
INDICATE TIRE OUT OF TOLERANCE/ BAD DATA
77
END
79

FIG. 4A

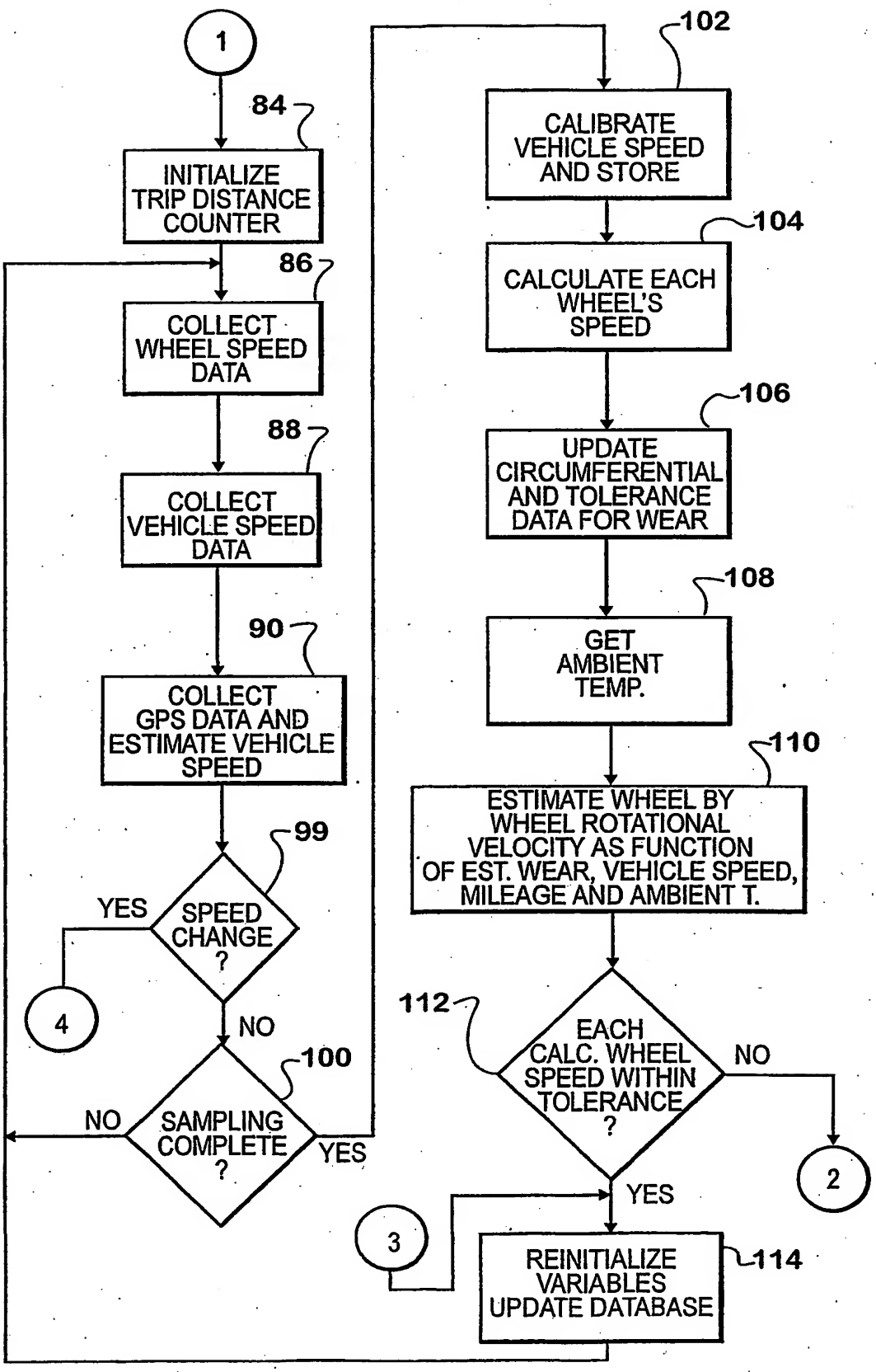
1
84
INITIALIZE TRIP DISTANCE COUNTER
86
COLLECT WHEEL SPEED DATA
88
COLLECT VEHICLE SPEED DATA
90
COLLECT GPS DATA AND ESTIMATE VEHICLE SPEED
99
SPEED CHANGE ?
YES
4
NO
100
SAMPLING COMPLETE ?
NO
YES
102
CALIBRATE VEHICLE SPEED AND STORE
104
CALCULATE EACH WHEEL'S SPEED
106
UPDATE CIRCUMFERENTIAL AND TOLERANCE DATA FOR WEAR
108
GET AMBIENT TEMP.
110
ESTIMATE WHEEL BY WHEEL ROTATIONAL VELOCITY AS FUNCTION OF EST. WEAR, VEHICLE SPEED, MILEAGE AND AMBIENT T.
112
EACH CALC. WHEEL SPEED WITHIN TOLERANCE ?
NO
2
YES
3
REINITIALIZE VARIABLES UPDATE DATABASE
114

FIG. 4B

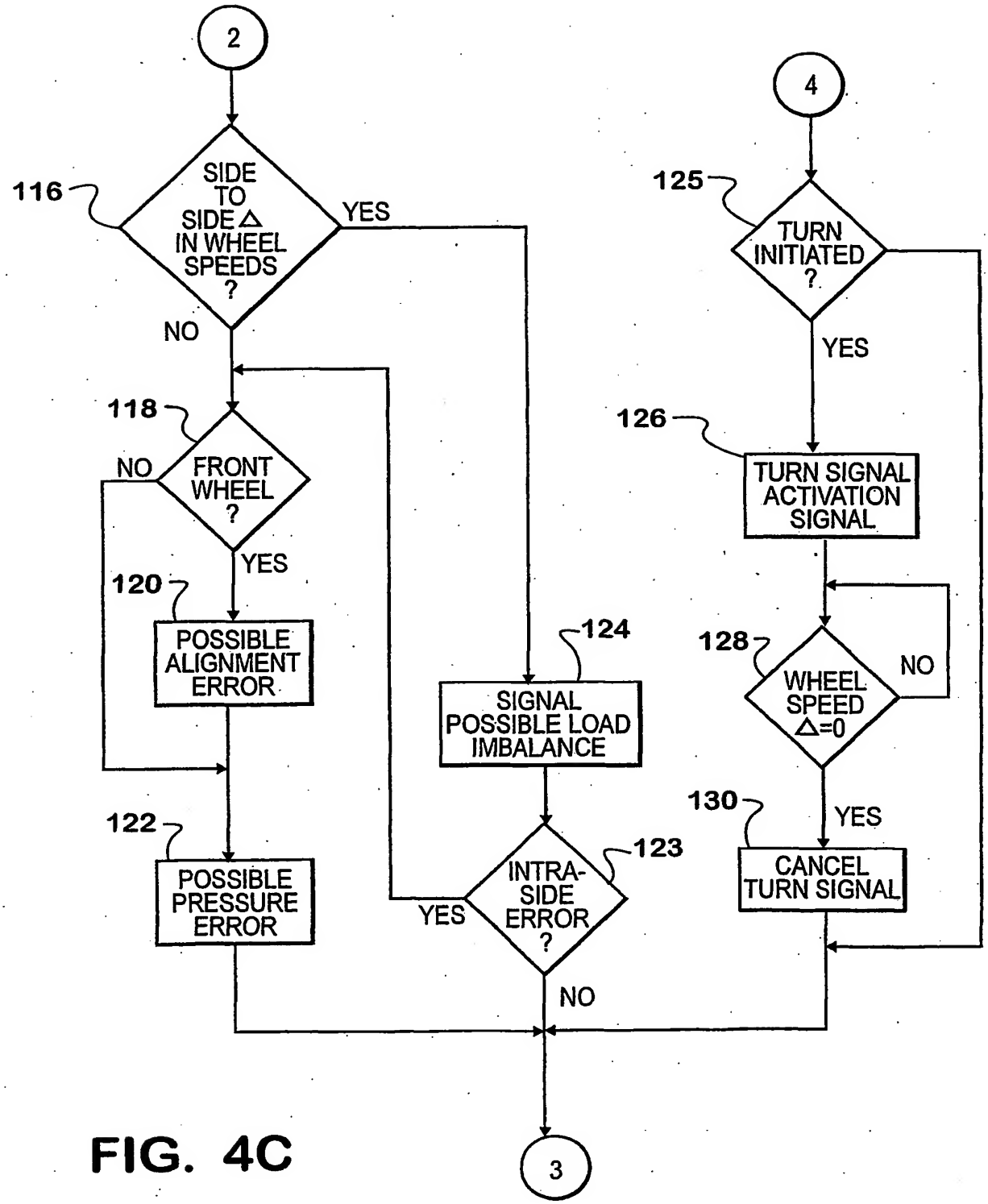
2
116
SIDE TO SIDE Δ IN WHEEL SPEEDS ?
YES
NO
118
FRONT WHEEL ?
NO
YES
120
POSSIBLE ALIGNMENT ERROR
122
POSSIBLE PRESSURE ERROR
124
SIGNAL POSSIBLE LOAD IMBALANCE
123
INTRA-SIDE ERROR ?
YES
NO
4
125
TURN INITIATED ?
YES
126
TURN SIGNAL ACTIVATION SIGNAL
128
WHEEL SPEED Δ=0
NO
130
YES
CANCEL TURN SIGNAL
3

FIG. 4C